



Studying the Upper Tropospheric Ozone Enhancements over North America: Initial Analysis with TES Observations and FLEXPART

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A31B - 0880

Motivation

- What is the ozone budget of North America? Specifically:
- What is the distribution of upper tropospheric ozone?
- How much is formed *in-situ* versus transported from the lower troposphere or subsided from the stratosphere?

Recent sonde campaigns (IONS and MONA) have started to provide a clearer quantification of southeast summer ozone.

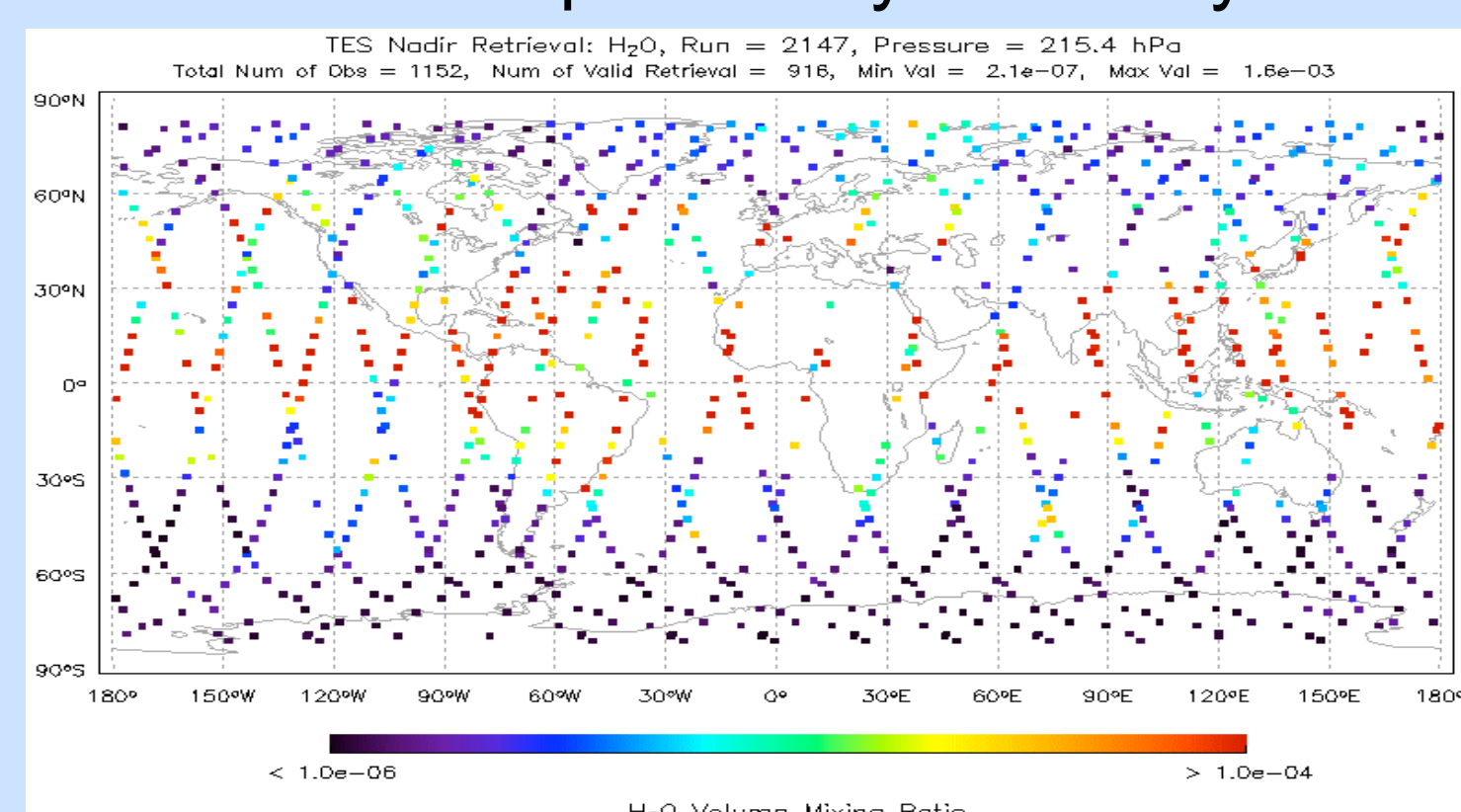
New remote sensing data sets provide a new set of observations for studying these questions:

TES - Tropospheric Infrared Spectrometer on EOS Aura

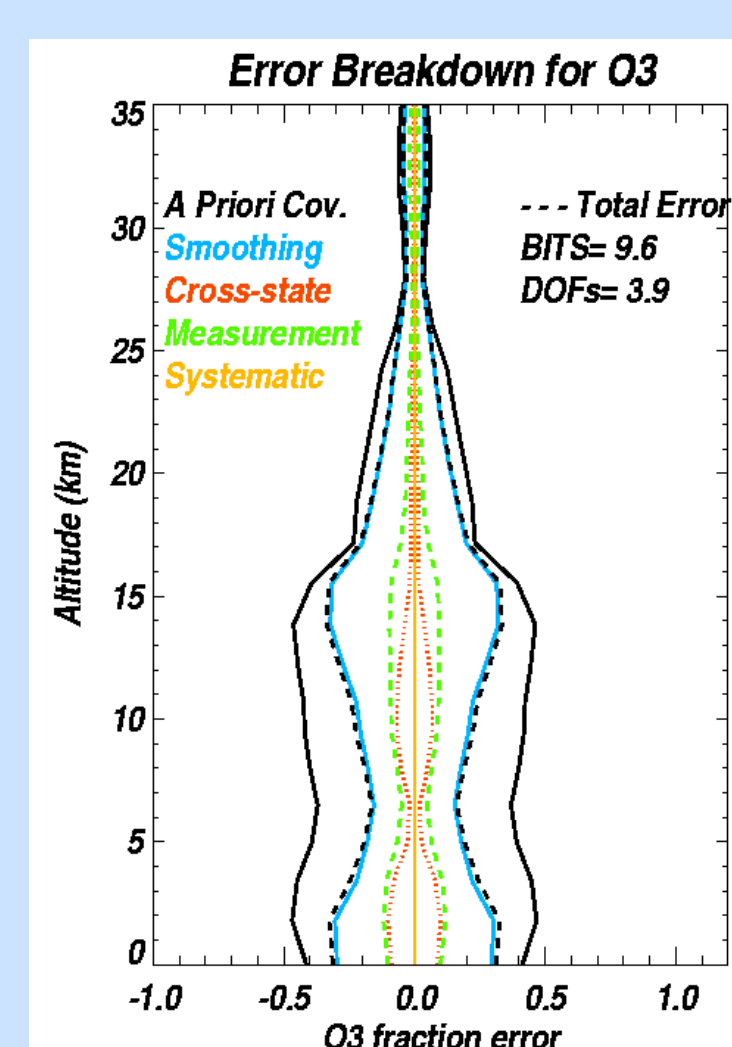
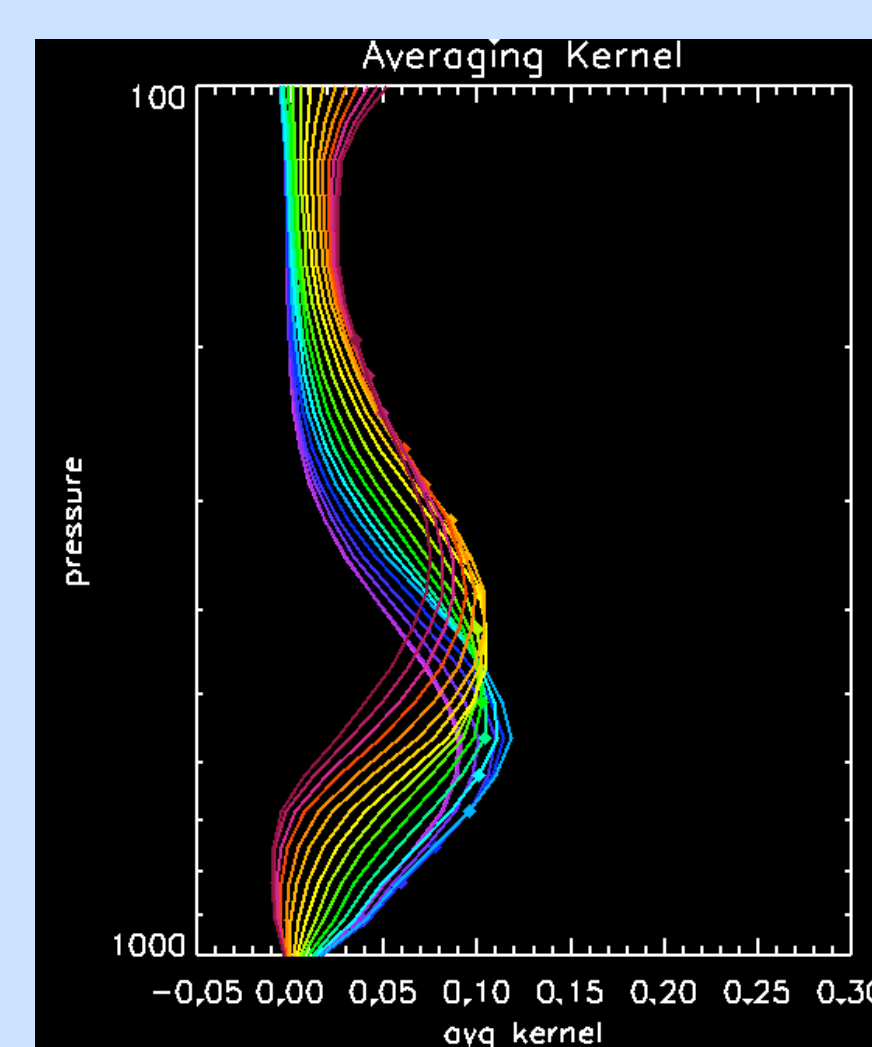
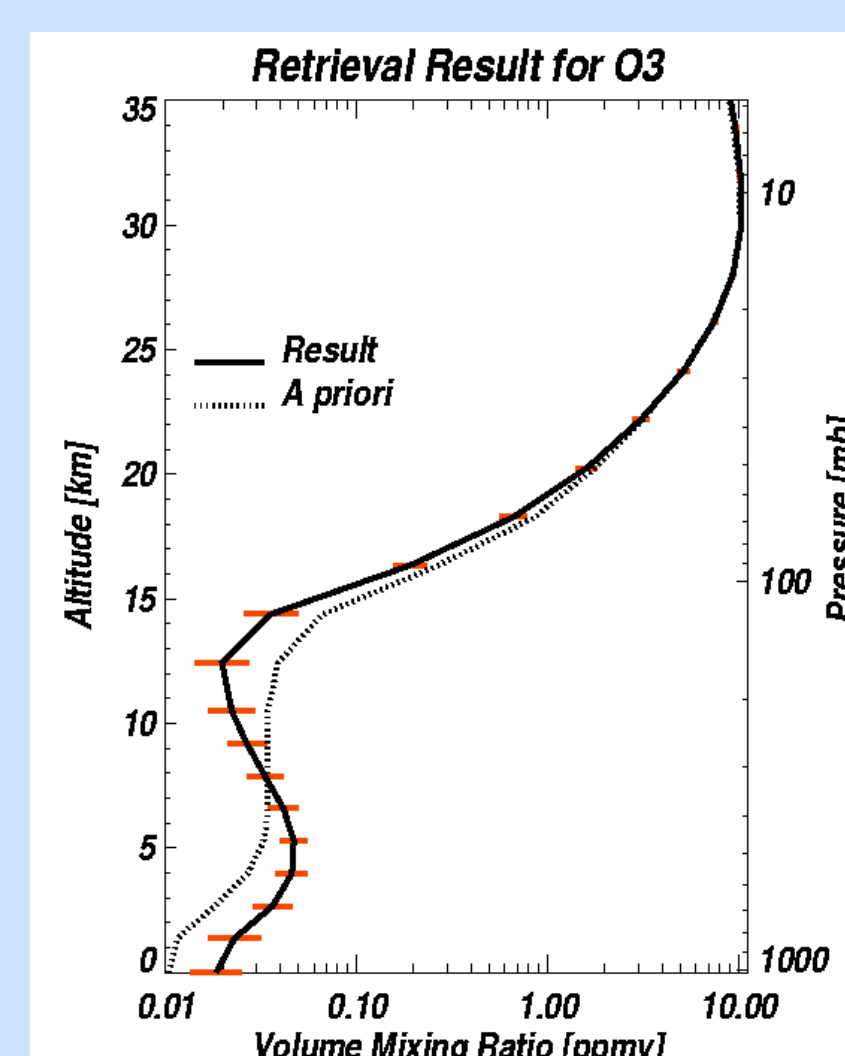
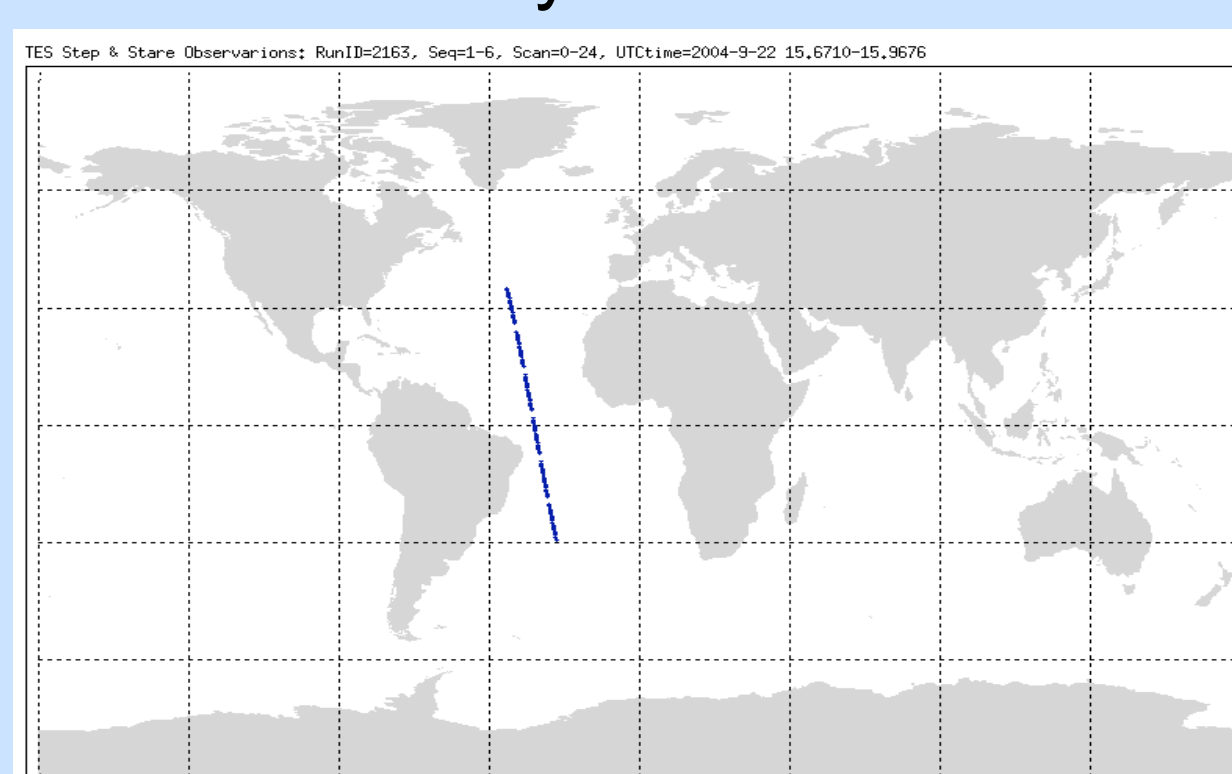
TES provides vertically resolved ozone and CO profiles globally, and can be used complement ozonesondes in investigations of the ozone budget.

TES Observations and Retrievals

Global samples every other day



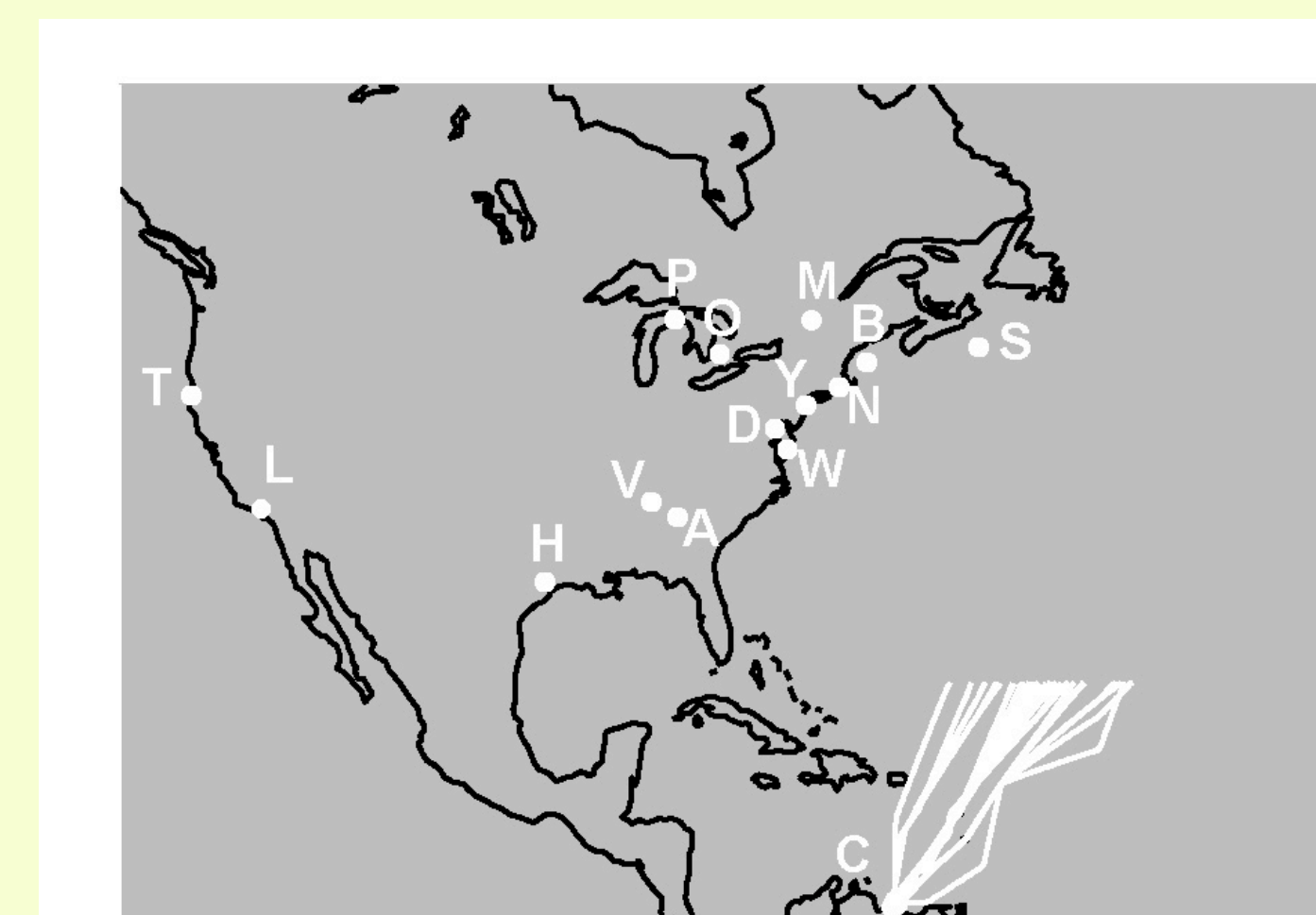
'Step and Stare' - densely sampled for special studies - used heavily in summer 2006



Optimal estimation is used, and provides retrieval profile, averaging kernel (indicating sensitivity), and error characterization. Clouds are treated in this same framework, and an effective cloud top pressure and effective optical depth at a set of about 25 frequencies are retrieved.

IONS/MONA Campaign

Summer ozone sonde campaign over North America were conducted in 2004 and 2006 with unprecedented coverage. On this poster, we will focus on the complementary TES measurements in August 2006.



Locations of IONS sonde launches in 2004 campaign

Analysis of the sondes by Cooper *et al* (2006) has shown that the elevated upper tropospheric ozone over the Southeast US in August 2004 was produced *in-situ*, and that lightning NO_x played an important role in this chemistry. Sonde measurements from a larger network in August 2006 will be used to further quantify the ozone budget.

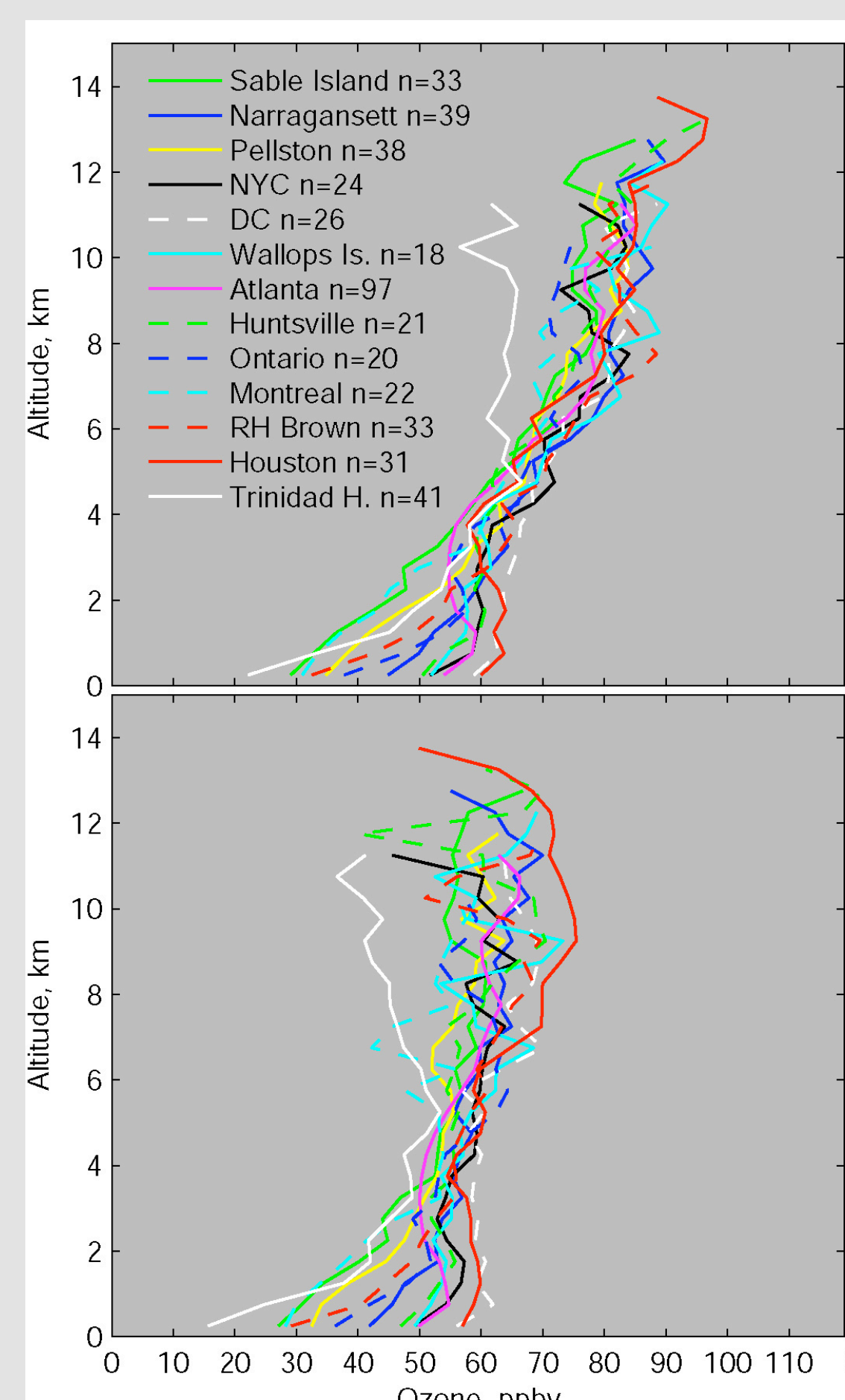
Analysis with FLEXPART

Cooper *et al* (2005, 2006) made comparisons between aggregated ozonesonde profiles.

FLEXPART retroplumes were used to quantify influence of the stratosphere on the measured air parcels. The ozone from the stratosphere was subtracted from the profile (using the ozone/PV ratio), and the adjusted profiles were compared.

From this analysis, Cooper *et al.* showed that the elevated upper tropospheric ozone over the southeast US that was observed with the summertime sonde campaign in 2004 could only be explained by *in-situ* formation driven by lightning NO_x. More on this in the talk **AE51B-05, Friday, 9:20am MCS 256.**

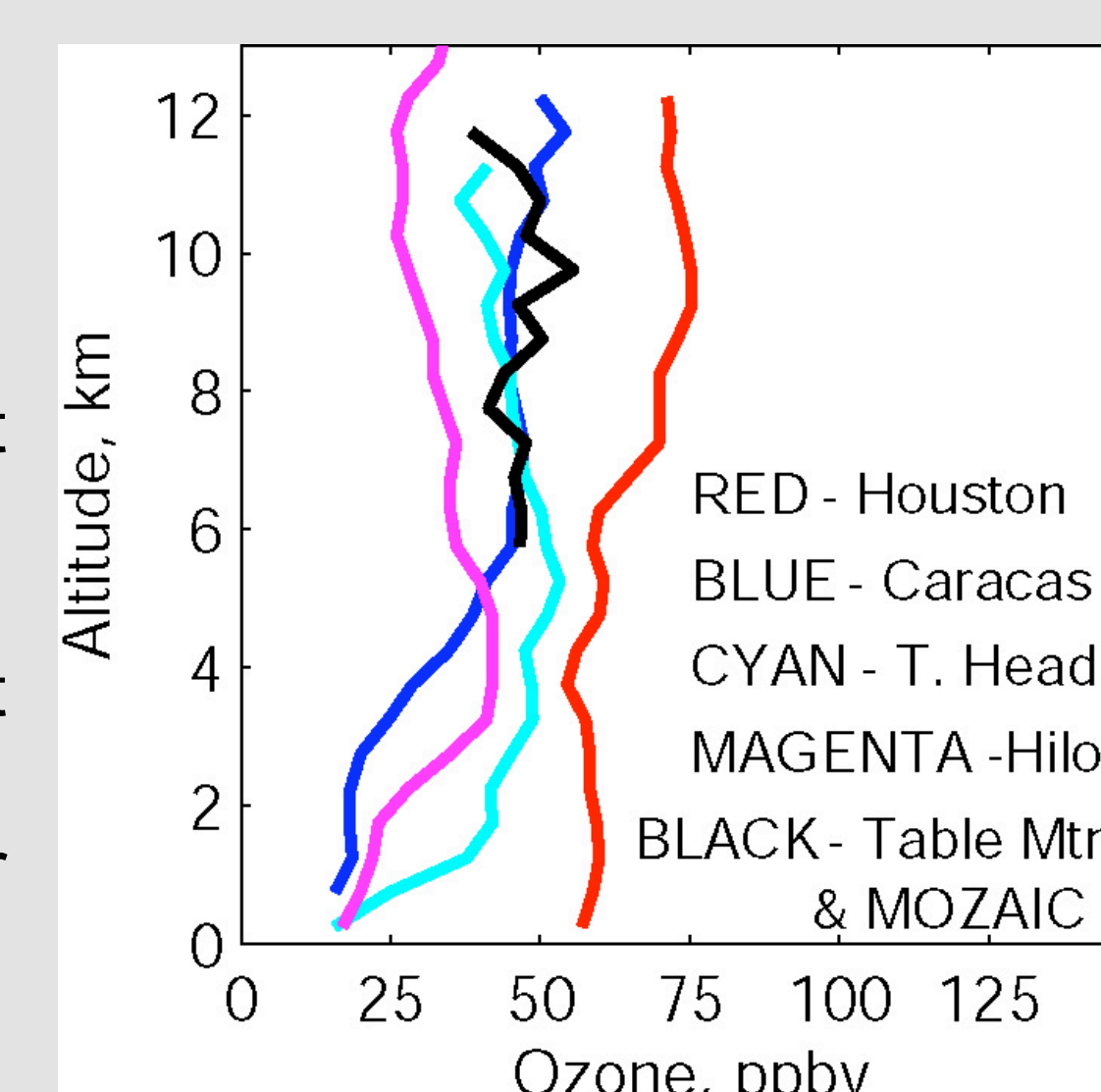
The work here focuses on using the TES remote sensing observations. The TES measurements offer the advantage of global coverage, although the vertical resolution is less than with ozonesondes.



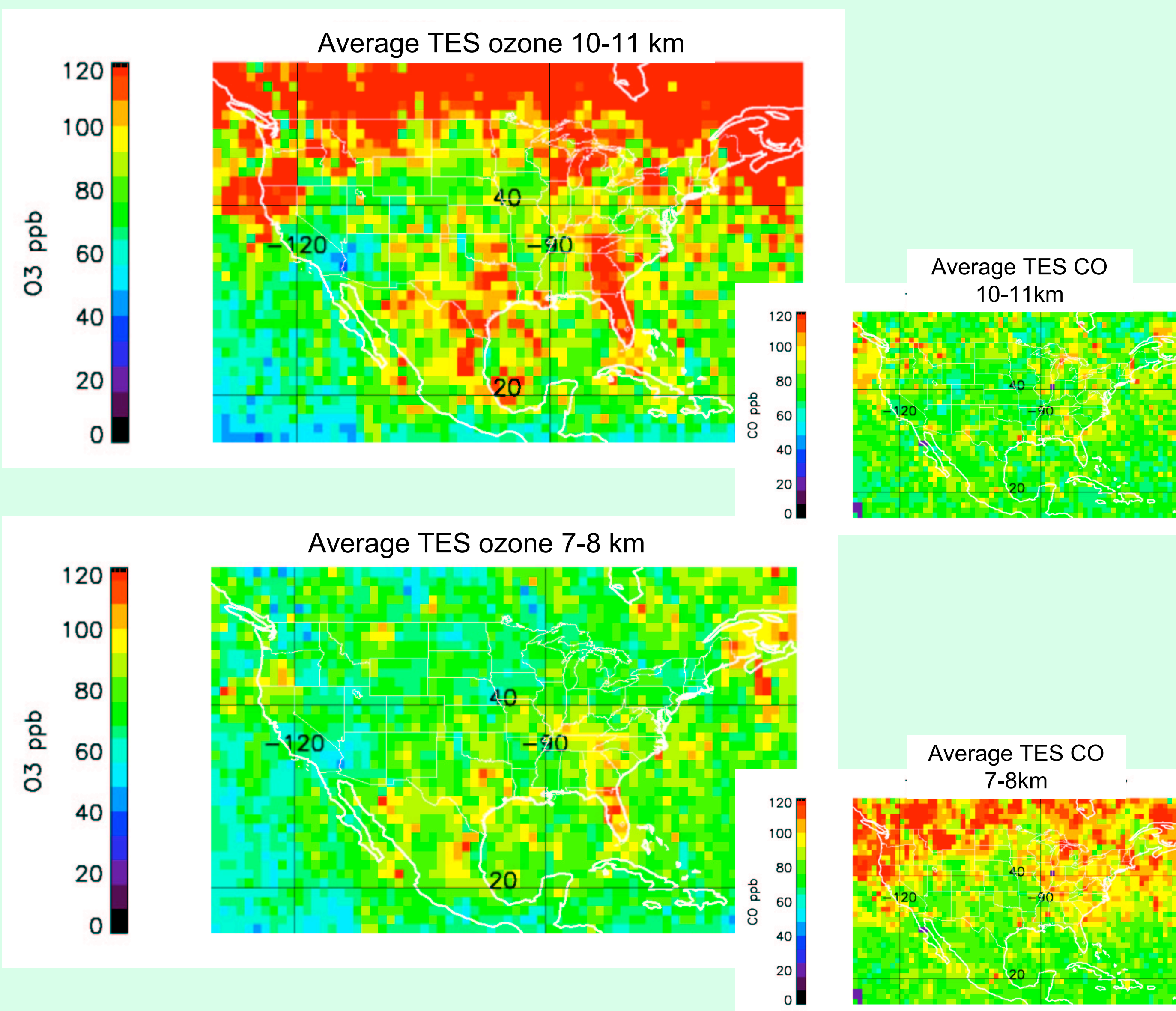
Upper panel: Ozone profiles in the troposphere measured during IONS 2004 campaign.

Lower panel: Ozone profiles after correction for the influence of stratospheric ozone.

Median ozone profile at Houston compared to upwind sites. The median ozone profile at Houston at 6km is on average 16 ppb greater than the upwind sites.

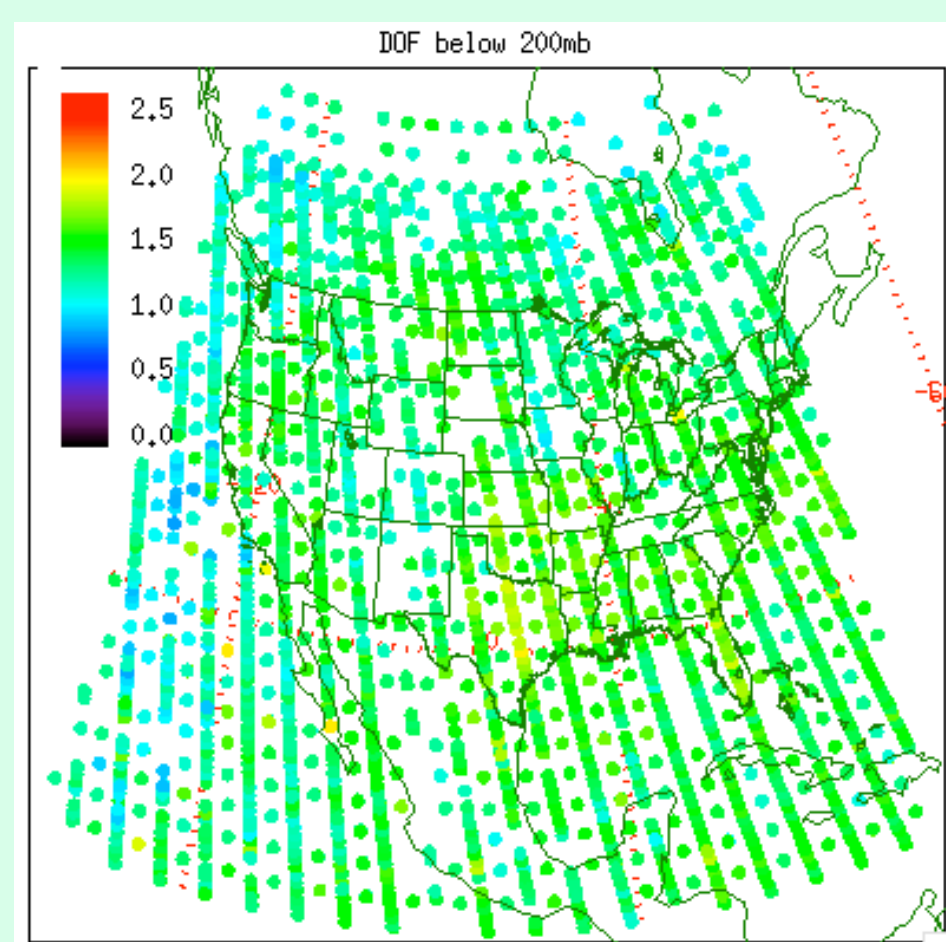


TES Observations August 2006:

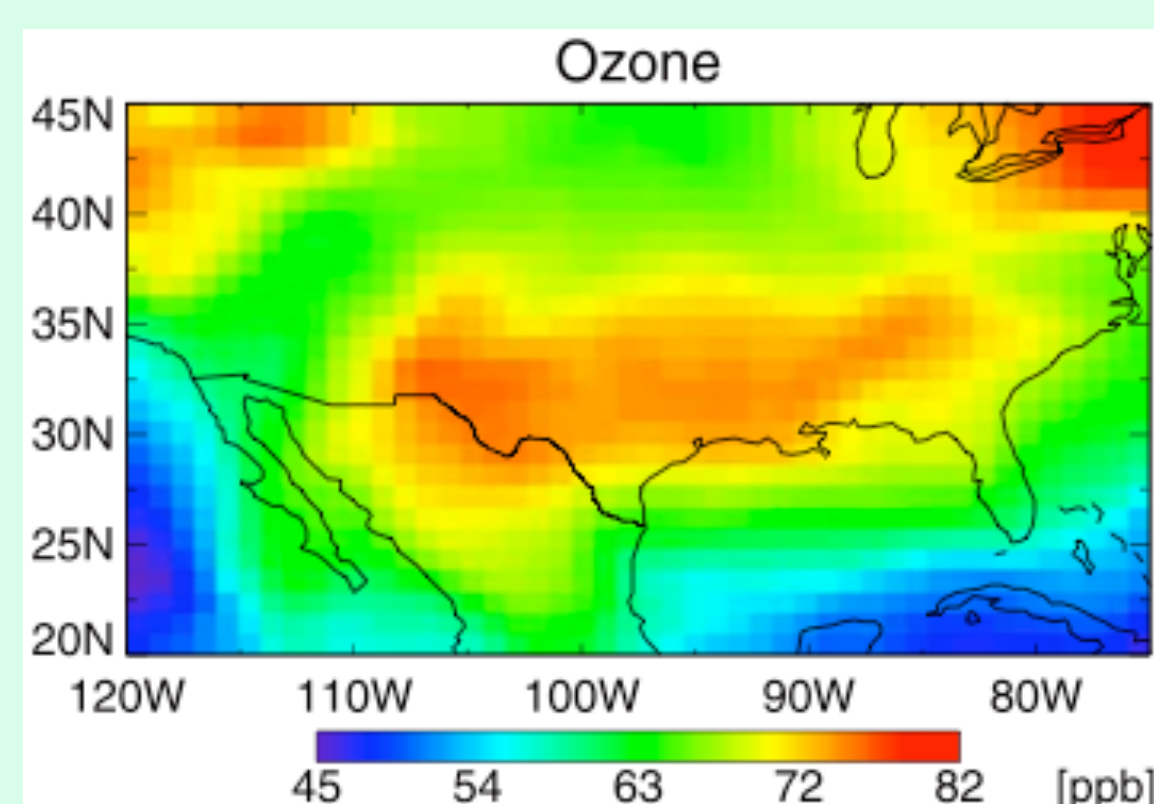


The figures above are maps of TES observations averaged over the month of August 2006 in 1km layers.

The upper tropospheric elevated ozone over the southeast is clearly present in the TES observations. The CO concentrations at 10-11km are not elevated over the southeast US, suggesting that lofting of surface pollution has not occurred.

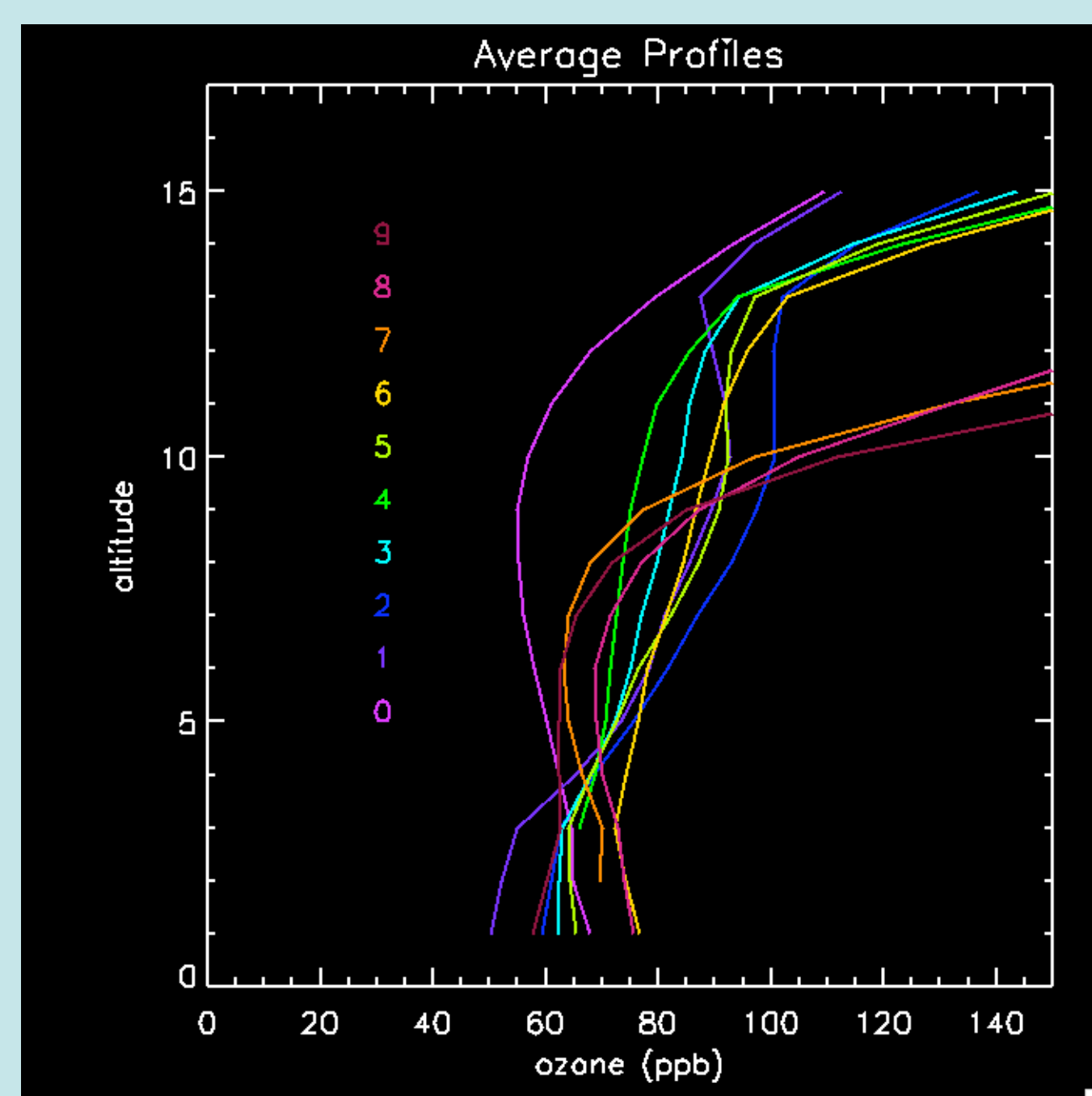


Each dot indicates the location of a TES observations. The degrees of freedom below 200mb. The sensitivity is influenced by surface temperature, water vapor, and clouds.



The figure above (from Li *et al* JGR, 2005) is a GEOS-CHEM simulation for July 2000. The overall features of southeast elevated ozone are similar to TES observations.

Aggregate Ozone Profiles

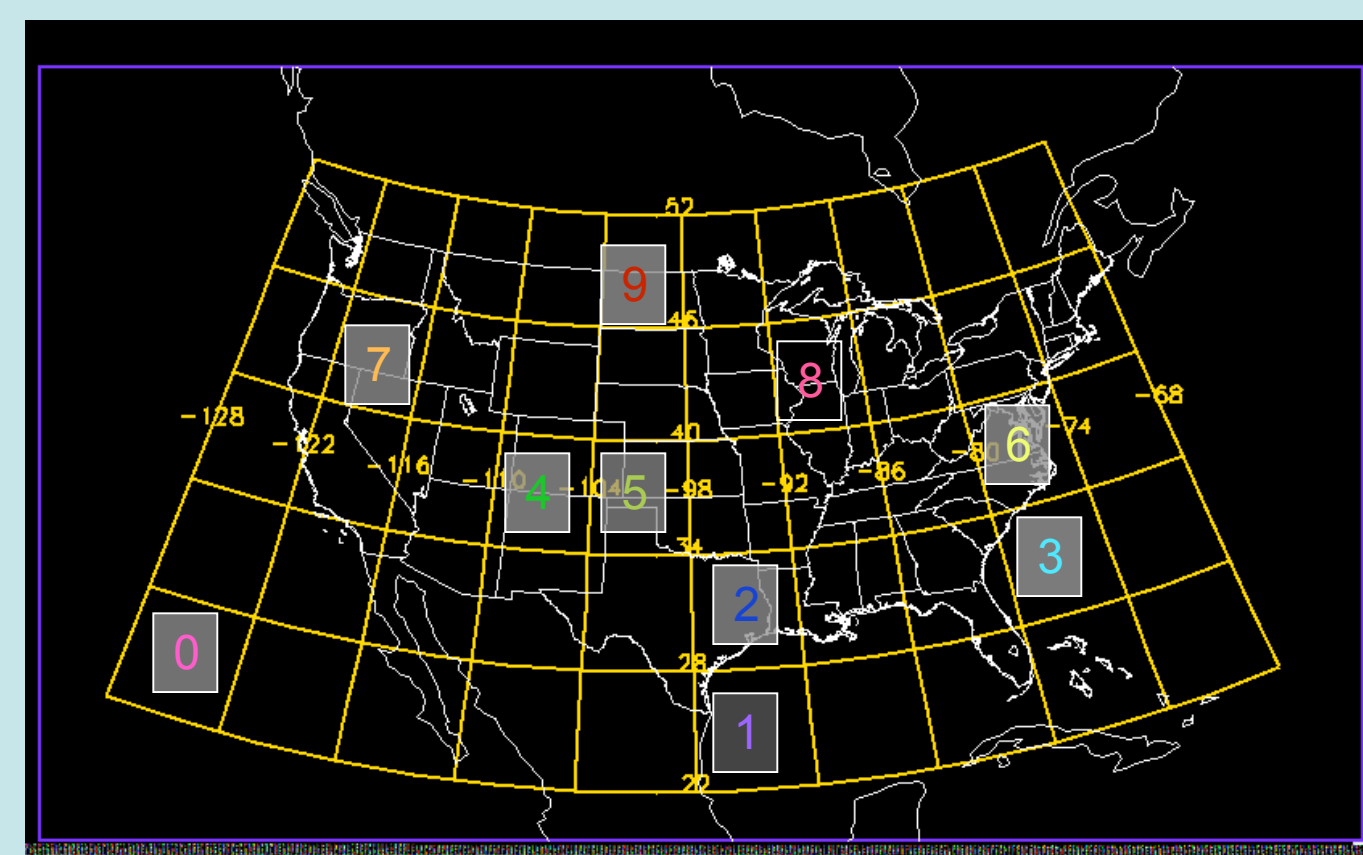


The figure above shows average TES ozone profiles in the grid boxes numbered to the right. These averages are of 30-60 profiles.

Profile 0 is an upwind profile with a high tropopause, in contrast to profiles 7, 8, and 9, which have low ozone in the upper troposphere, but have a tropopause near 8 km.

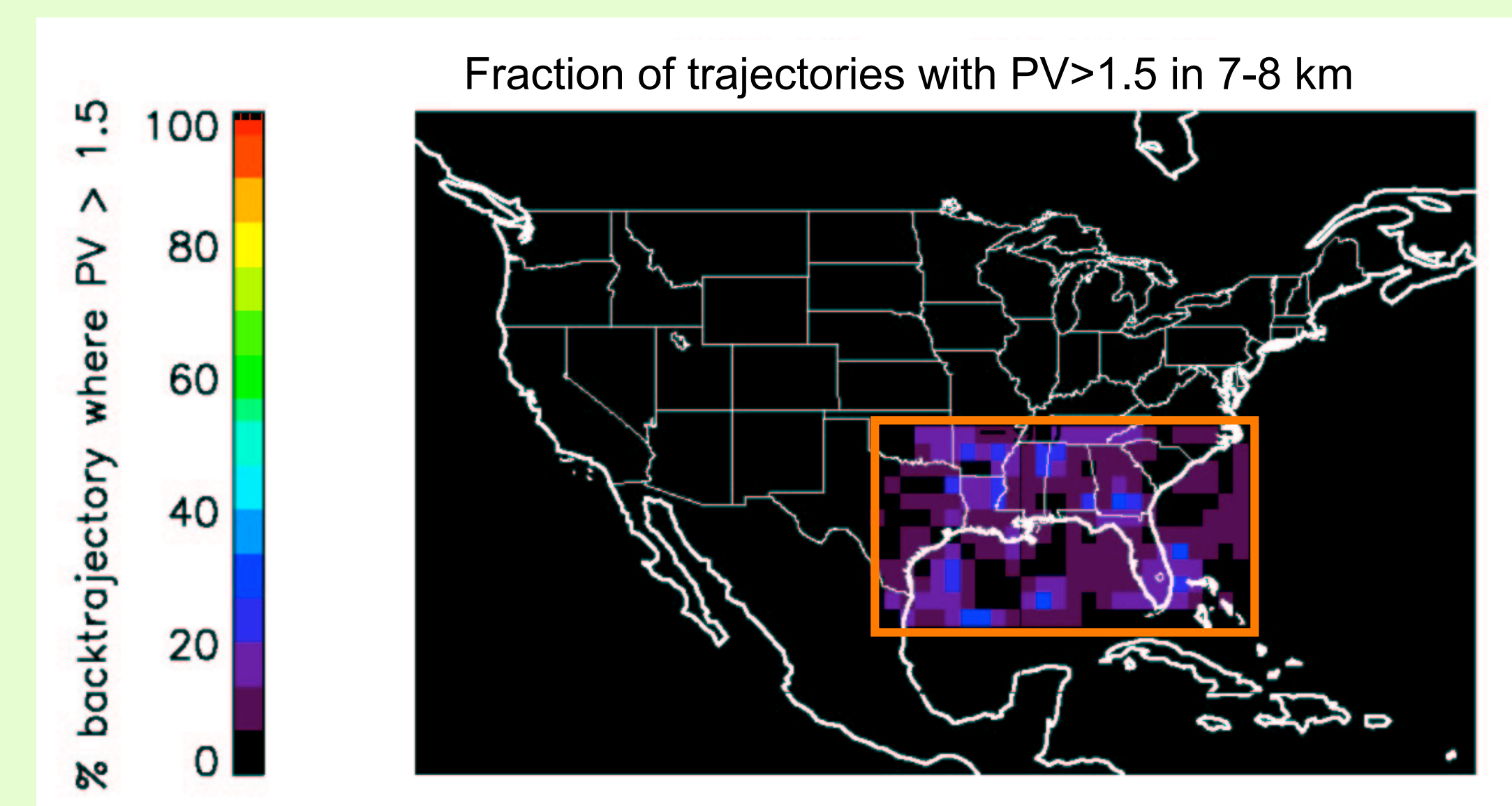
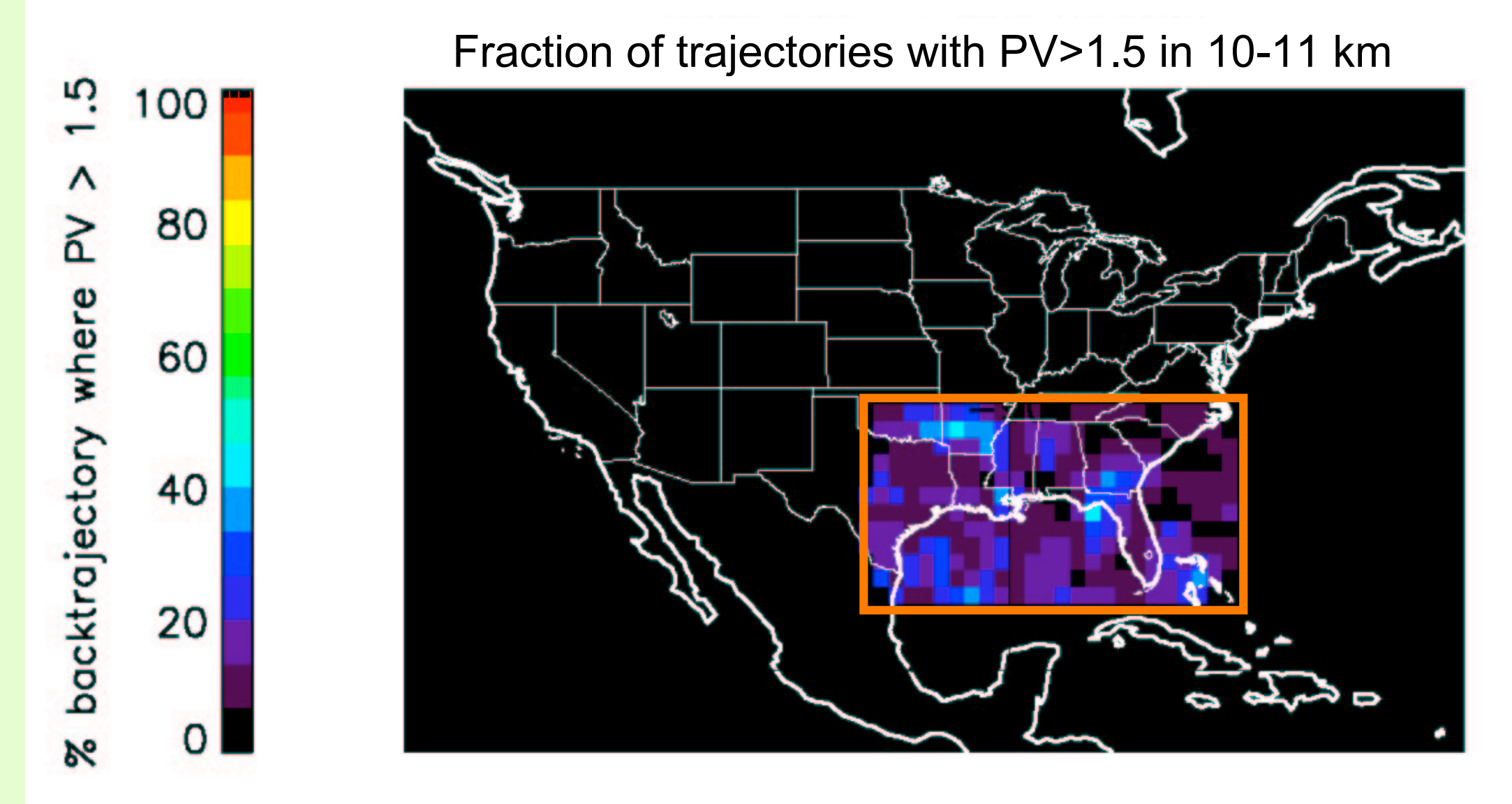
Profiles 1 through 6 show elevated ozone in the upper troposphere.

More detailed analysis of the averaging kernels (not shown here) shows that TES has good sensitivity in the middle to upper troposphere for the data shown here.



Quantifying the Influence of Stratosphere:

FLEXPART runs have been conducted for the Southeastern US TES measurements (orange boxes below). These can be used to quantify the impact of the stratosphere on the upper tropospheric ozone measurements.



These retrorplumes show that there is very little stratospheric influence in most of the 10-11km layer above the southeast US. In the 7-8km layer, the stratospheric influence is negligible.

Additional retrorplumes will be run, and then an adjustment will be made to each ozone profile to remote the stratospheric influence, following the method of Cooper.

Conclusions

- TES on EOS Aura is providing the first vertically resolved measurements of tropospheric ozone from space. Along with the ozone measurements, we retrieve profiles of water vapor, temperature, and CO. Effective cloud top pressure and cloud optical depth are determined in this retrieval.
- TES observations complement the ozonesonde measurements, and are particularly valuable for providing information about the off shore fields not sampled by ozonesondes. TES is primarily sensitive to the middle and upper troposphere, with some sensitivity to the lower troposphere over warm surfaces
- TES measurements show a similar distribution of ozone as the sondes in Aug 2004 and 2006 - elevated ozone over the southeast in the upper troposphere.
- FLEXPART retrorplumes will be used to quantify the influence of the stratosphere and *in-situ* formation on upper tropospheric ozone over the southeast US.

IMPORTANT WEBSITES:

<http://tes.jpl.nasa.gov> - a great starting point about the data, the instrument, and the team

<http://eosweb.larc.nasa.gov/> - The starting point for data access - v003 data is now being delivered

The ASDC Data pool will have the data processed in the last 12 months (<http://eosweb.larc.nasa.gov/HPDOCS/datapool/>)

Acknowledgements: A portion of this work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. This work relies on the efforts of the TES team: R. Beer, K. Bowman, S. Kulawik, J. Worden, H. Worden, G. Osterman, M. Luo, B. Fisher, D. Rider, and more....